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Degradation of Soil Quality Parameters Due to Coal Mining Operations in Jharia Coalfield, Jharkhand, India

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Abstract: Coal mining for an area is an economic activity but may lead to degradation of soil quality. Open-cast coal mining operations involved displacement of a large amount of overburden/rock mass materials to excavate the coal for many purposes. In mining areas, the soils are affected by various coal mining operations i.e. blasting, drilling, storage of overburden dump materials, clearing of land, construction of ancillary facilities and movement of vehicles. Various wastes such as heavy metals, inorganic substances, toxic materials and organic substances are released from different process of coal mining operations. The study was conducted during 2009 in six sampling locations of the Jharia coalfield, Dhanbad, Jharkhand state. The study revealed that significant variation in physicochemical parameters of soil due to coal mining operations. The information obtained from this paper helps in knowing about the quality of soil status in Jharia coalfield, Jharkhand state. This paper will focus on the characterization of soil and will discuss the significance of these parameters with an emphasis on N, P, and K.

Keywords: Coal, Open-cast mines, Electrical conductivity, Organic carbon, Available nitrogen.

1. Introduction

Coal is the dominant energy source in India. The thermal power plants use coal as a fuel. The major portion of coal is of low quality and low calorific value. About 70% of India's coal production is used for power generation, with the remainder being used by heavy industry and public use. The available coal reserves in India are sufficient to meet our needs for at least another 100 years. India ranks third amongst the coal producing countries in the world; it produces only limited quantities of coking coal needed by its steel plants. As a result, it is a large importer of coking coal, mostly from Australia. Most of the coal production in India comes from open cast mines which contribute over 81% of the total production. A large number of open cast mines over 10 million tonnes per annum capacity are in operation in India. Underground mining currently accounts for around 19% of national output. Most of the coal production is achieved by conventional Bord and Pillar mining methods. Coal mining operations are only economic when the coal seam is near the surface of the land. Surface mining not only destroys the existing land use pattern, air quality, water quality and vegetation but there is also a loss of topsoil, in either pedagogical or a biological sense. In addition to, flora and fauna along with its hydrological relations are drastically disturbed due to open-cast mining operations. Coal resources in India (in Million Tonnes) are given in Table 1. In Fig. 1, simple view of open-cast mines is shown.

Soil comprises physical, chemical and biological substances which show alternations in its quality due to the impact of various coal mining operations. Open-cast activities such as blasting, drilling and transportation of coal materials have not only changed the look of adjoining mining areas but have also left inorganic substances and toxic traces on the soil systems.

Table 1. Coal resources in India (in Million Tonnes).

Year	Proved	Indicated	Inferred	Total
2004	91631	116174	37888	245693
2005	92960	117090	37797	247847
2006	95866	119769	37666	253301

Source: www.eai.in, 2007

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Table 2. Changes in Land use due to open-cast mining (Source: Raju, 2007).

S. No.	Types of land use	Land use changes due to mining
1	Agricultural land	Excavated for mineral extraction, covered by solid waste dumps and setting up of mining infrastructure.
2	Forest covers	Degraded forest with erosion problems, removal of forest cover for excavation.
3	Natural water bodies	Smaller streams and ponds are filled, choked or dried.
4	Settlements	Shifted for excavation, dumping wastes and setting up of mining infrastructure.

Fig. 1. Degradation of topsoil due to coal mining operations, JCF.

Fig. 2. Degradation of soil quality in Jharia coalfield, Jharkhand.

The environmental degradation affects the flora and fauna of the region to a large extent. Due to lack of proper planning and negligence of mining regulations, an appreciable amount of environmental degradation and ecological damage to soil occurs (Dhar, 1993). Dumping of huge amounts of mining waste materials from coal mining operations on agricultural land to destroy soil fertility causes delays ecological plant succession affecting local biodiversity of the Jharia coalfield (Jha & Singh, 1992). In Jharia coalfield, topsoils are not selectively handled as a result of the topsoil material gets mixed with overburden rock mass from coal mining operations and thus the soil fertility, an important resource for land management is lost slowly. Dalka *et al.*, 1976 reported that heavy metals associated with mining are known to have toxic properties if present in above certain levels. Wali, 1975 reported that heavy metals like Fe, Mn, Cu, Pb, Cd, Cr and Co etc. of which are known as essential elements for plant growth, but almost all become phytotoxic at higher concentration. However, there is scarcity of work on physicochemical characteristics of soil of coal mining areas in India. Environmental impacts of open-cast mining on land are summarized in Table 2.

2. Materials and Methods

2.1 Study area

The Jharia Coalfields (JCF) is one of the Lower Gondwana coalfields of India, covering an area of about 72 km^2. It is one of the most important coalfields in India, located in Dhanbad district, between latitude 23° 39' to 23° 48' N and longitude 86° 11' to 86° 27' E. This sickle shaped coalfields is about 40 km in length and approximately 12 km in width stretches from West to East and finally turns southward covering an area of about 450 sq.km (Fox, 1930). Jharia coalfield (Jharkhand) is the single source of coking coal for prime quality in India. The coalfield has been a centre of coal mining activity for more than a century. The average maximum temperature recorded during April and May is about 37^0C - 41^0C. The average minimum temperature is about 7^0C-10^0C recorded usually during the months of December and January. The map of the study area is shown in Fig. 3. The six sampling sites were selected in the mining area of Jharia coalfields i.e. Bararre, Bansjora, Gonudih, Sonardih, Gaslitand and Jogidih. The brief details of sampling locations in Jharia coalfield are given in Table 3.

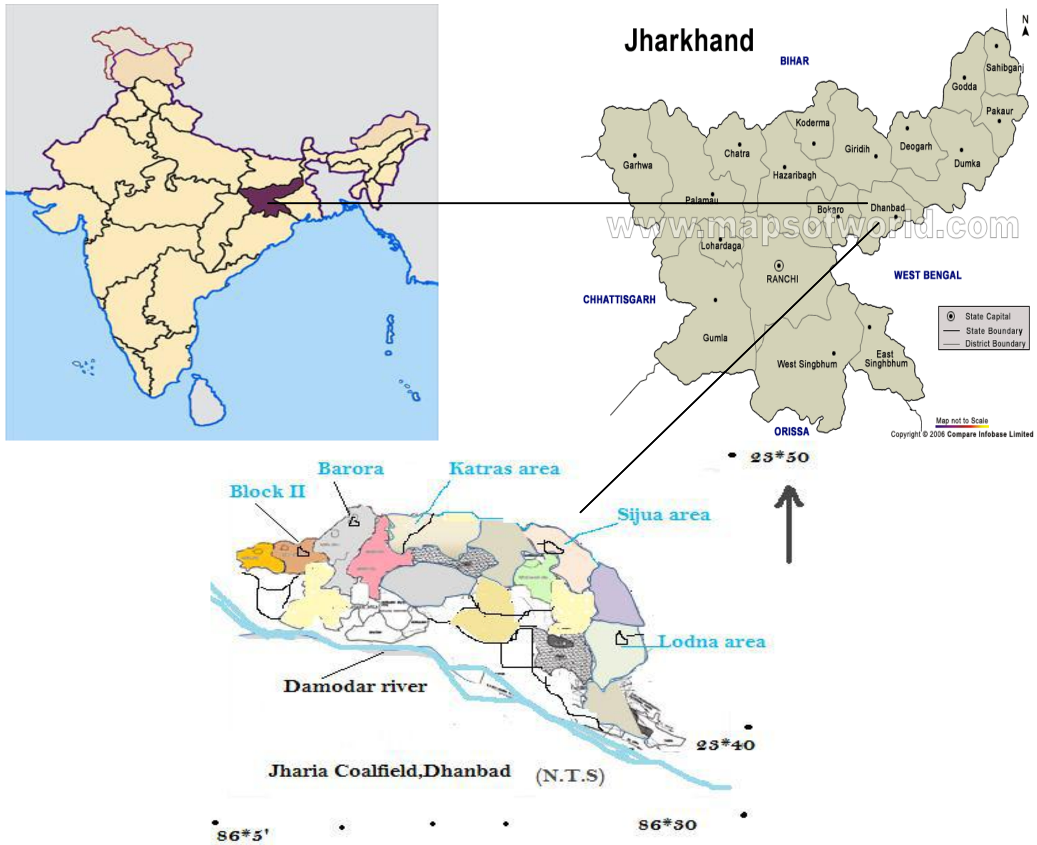

Fig. 3. Map of study area, JCF

Table 3. Brief details of sampling locations in Jharia coalfield, Dhanbad

S. No.	Sampling locations	Colliery area	Coalfield
1	Bararre	Lodna area	Jharia coalfield
2	Bansjora	Sijua area	Jharia coalfield
3	Gonudih	Sijua area	Jharia coalfield
4	Sonardih	Katras area	Jharia coalfield
5	Gaslitand	Katras area	Jharia coalfield
6	Jogidih	Barora area	Jharia coalfield

2.2 Collection of samples

In the present study, about six soil samples were collected from the various selected sites of Jharia coalfield, Dhanbad during the month of the summer season. The samples were collected in a clean polythene bags, properly packed and the analysis was carried out in the Department of Environmental Science and Engineering, ISM, Dhanbad. The soil samples were air dried, cleaned, crushed and passed through 2mm mesh sieves and analyzed in the laboratory. The study has been carried out for moisture content, bulk density, pH, electrical conductivity, organic carbon, available nitrogen, available phosphorus and available potassium.

2.3 Methodology

The moisture content was determined by gravimetric method. It is expressed as a percentage. Bulk density was also measured by gravimetric method. pH and electrical conductivity were determined using pH meter and conductivity meter. Organic carbon, Available nitrogen, Available phosphorus and Available potassium were determined using Wadley and Black method (Nelson and Summers, 1982), alkaline permanganate method (Keeney and Bremer, 1966) and Bray method (Bray and Kurtz, 1966) respectively.

3. Result and Discussion

The results of the physical-chemical analysis of the soil of JCF are presented in Table 4.

Moisture content indicates the amount of water present in the soil. The moisture content of soil can be expressed in percentage. The amount of water stored in the soil is not constant with time but may vary with time to time. The moisture content of the selected soil was found to be ranged from 9.7% to 13.8%. The moisture content of the soil was found lower at Bansjora (9.7%) due to presence of rocky mass materials and vice versa. The moisture content of the soil was found higher at Sonardih (13.8%) and Gonudih (13.0%), indicating well for normal growth of plants. This data gives an idea about the normal growth of plants in a coal mining area.

Table 4. Soil quality parameters of different sampling sites of Jharia coalfield.

		Units	Sampling sites (Average values)					
S. No.	Parameters	-----	Bararre	Bansjora	Gonudih	Sonardih	Gaslitand	Jogodih
1	Moisture content	%	10.5	9.7	12.4	13.8	13.0	11.4
2	Bulk density	gm/cc	1.54	1.51	1.47	1.41	1.39	1.44
3	pH	---	5.83	5.42	6.04	6.13	5.47	6.21
4	Electrical conductivity	mmhos/cm	0.43	0.48	0.37	0.34	0.27	0.31
5	Organic carbon	%	0.39	0.43	0.54	0.57	0.49	0.41
6	Available nitrogen	kg/ha	222.96	231.4	234.2	225.4	236.8	227.3
7	Available phosphorus	kg/ha	1.10	0.75	1.32	1.14	0.91	1.18
8	Available potassium	kg/ha	137.6	129.2	142.4	133.7	130.5	134.2

Bulk density is a measure of the weight of the soil per unit volume, usually given on an oven dry basis. Most mineral soils have bulk densities between 1.0gm/cc and 2.0gm/cc (Braddy & Well, 2002). Bulk density of soil samples is quite variable from one site to another site. It also depends on the texture, soil structures and organic matter status of the soil (Maiti, 2003). Bulk density of soil was found to be between 1.39gm/cc to 1.54gm/cc. Bulk density of soil was found lower at Gonudih 1.39gm/cc due to the presence of high organic matter in the soil. Bulk density of soil was found higher at Bararre (1.54gm/cc) and Bansjora (1.51gm/cc) due to less amount of organic matter present in the soil system.

pH is a measure of acidic or basic properties of the soil and is measured using a pH scale between 0 to 14 with acidic things having a pH between 0-7 and basic things having a pH from 7 to 14. The pH of the soil solution is very important because the soil solution carries in it nutrients such as Nitrogen (N), Potassium (K) and Phosphorus (P) that plants need in specific amounts to grow, thrive and fight off diseases (Biswas *et al*., 1994). Maiti, 2003 found that greater depths pH was found to be more acidic. The maximum availability of the primary nutrient like nitrogen, phosphorus and potassium as well as secondary nutrients like sulphur, calcium and magnesium are found in the pH range of 6.5 to 7.5 (Ghosh *et al*., 1983). In the present study, pH of soil samples was found to be lower at Bansjora (5.42) and higher amount at Jogidih (6.21). Low pH at the Bansjora can be attributed to oxidation of pyrite particles in the soil samples and high at the Jogidih due to absence of pyrite particles in the soil samples. The higher pH indicated optimal range for plant growth but lower pH cause problems for normal growth of the plants. Almost similar observations were recorded by (Tripathy *et al*., 1998) while studying on the soils of the Jharia coalfield in Dhanbad.

Electrical conductivity (EC) is the most common measure of soil salinity and is indicative of the ability of an aqueous solution to carry an electric current. It is well established that conductivity 0.2dS/m - 0.8dS/m is the optimal range for plant growth. Plants are affected, both physically and chemically, by excess salts in some soils and by high levels of exchangeable sodium in others (Saxena, 1987). During the study period, the EC was found to be ranged 0.12 mmhos/cm to 0.88 mmhos/cm in different sites of Jharia coalfield. The higher valued in Bararre (0.63 mmhos/cm) and Bansjora (0.88 mmhos/cm), were due to upward migration of different salts with spontaneous combustion of coal particles in and around the sampling sites. The minimum value observed at Tundoo (0.17 mmhos/cm) and Guhibandh (0.12 mmhos/cm). This might be due to the lower amount of different salts present in the soil samples.

Organic carbon is important parameters of soil because it improves both the physical and chemical properties of soil and has several beneficial effects on agricultural soil quality. It also improves soil structure, enhances aeration, water penetration, and increases water-holding capacity and supplies nutrients for growth of plants. Organic carbon levels greater than 0.8% is rated as good quality of soil (Saxena, 1987). The amount of soil organic carbon (SOC) depends on soil texture, climate, vegetation and historical and current land use/management. Soil texture affects SOC because of the stabilizing properties that clay has on organic matter. Organic matter can be trapped in the very small spaces between clay particles making them inaccessible to microorganisms and therefore slowing decomposition. In the present study, the organic carbon content in soil samples varied from 0.39% to 0.57% in selected sampling sites of Jharia coalfield. The organic carbon in Bararre (0.39%) were found low due to lack of several microbes, low humification, rate, lack of weeds in the sampling sites, whereas high organic carbon were recorded at Sonardih (0.57%) due to higher amount of humic substances present in the soil samples from decomposition of garbage wastes dumped on the soil. Organic carbon level in most of the soil samples has been found poor in range.

Nitrogen (N) in the soil is the most important element for plant development. Soil nitrogen exists in three general forms organic nitrogen compounds, ammonium ions and nitrate ions. The plants are surrounded by the N in our atmosphere. Every acre of the earth's surface is covered by thousands of pounds of this essential nutrient, but because atmospheric gaseous nitrogen is present as almost inert nitrogen molecules, thus nitrogen is not directly available to the plants that need it to grow to develop and reproduce. Healthy plants contain 3% to 4% nitrogen in their above ground tissues (www.rainbowplantfood.com). It is required in large amounts and must be added to the soil to avoid a deficiency. Several researchers reported that nitrogen may enter the soil through rainfall, plant residues and nitrogen fixation by soil organisms, animal manures and commercial fertilizers. In the present study, available nitrogen was found to be ranged 222.96 kg/ha to 236.8 kg/ha in different sampling sites of Jharia coalfield. The higher values (236.8 kg/ha) recorded at Guhibandh, due to higher amount of mineralizable organic nitrogen present in the soil samples and lower values (222.96 kg/ha) recorded at Bararre site due to lower rates of the mineralization process in the soil samples.

Phosphorus (P) is an essential element classified as a macronutrient because of the relatively large amounts of phosphorus required by plants. Phosphorus is one of the three nutrients generally added to soils in fertilizers. It has been found by several scientists that the main roles of phosphorus in soils are the transfer of energy. A sufficient number of phosphorus availability for plants stimulates early plant growth and hastens maturity. So, Phosphorus is essential for plant growth in a coal mining area and mismanagement of soil phosphorus can pose a threat to water quality and soil quality directly or indirectly ways. In the present study, available phosphorus was found in the range of 0.75 kg/ha to 1.35 kg/ha. The phosphate content of the soil samples was recorded in low amount (0.75 kg/ha) at Bansjora site. This might be due to the acidic nature of soil which restricted the microbial action activities resulting very poor mineralization process in the soil samples and high values recorded (1.35 kg/ha) at Gonudih site due to slightly alkaline nature of soil.

Potassium (K) is an essential nutrient for plant growth. Three forms of K (unavailable, slowly available or fixed, readily available or exchangeable, soil solution potassium) exist in soils. Exchangeable potassium is readily available potassium, which plants can easily absorb. This fraction of potassium is held on the surface of clay particles and organic matter in soil. It is found in equilibrium with the soil solution and is easily released when plants absorb potassium from the soil solution. Exchangeable potassium is measured in most soil testing (www.smartfertilizer.com). Because large amounts are absorbed from the root zone in the production of most agronomic crops, so it is classified as a macronutrient. Depending on soil type, approximately 90-98% of total soil K is found in this form. The exact function of K in plant growth has not been clearly defined. Saxena *et al*., 2005 have suggested that plants in the coal mining area cannot use the K in crystalline-insoluble form and over long periods of time, these minerals (feldspars or mica) weather (breakdown) and K is released in the soil samples. This process is too slow to supply the full K needs of the plantation. If K is not supplied in adequate amounts, plant growth is stunted in coalfield areas. In the present study, available potassium varied from 129.2 kg/ha to 142.4 kg/ha. The potassium content of the soil samples was recorded in low (129.2 kg/ha) amount at Bansjora site. This might be due to very poor mineralization process in the soil samples and high values recorded (142.4 kg/ha) at Gonudih due to medium rates of weathering or mineralization processes in the soils.

4. Conclusion

On the basis of physicochemical analysis of soils in the Jharia coalfield area the following conclusions are drawn:

It has been found that continuous coal mining activities in the Jharia coalfields have posed a severe threat to several components of environment by generating a huge amount of coal mining wastes. The coal mining wastes cause very serious pollution in terms of soil quality and cause a long-term disaster to the natural ecosystem. Moisture content, bulk density, pH and electrical conductivity have been found moderate in range for plant growth in the sampling sites of Jharia coalfield. In all the soil samples concentrations of organic carbon, available nitrogen, available phosphorus and available potassium have been found low as compared to normal soils. From the above discussion, it can be concluded that the soil samples evaluated in this study weren't found environmentally safe for plantation, vegetation and agricultural purposes.

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Abbreviations:

1. **GSI:** Geological Society of India.
2. **JCF:** Jharia coalfield, Jharkhand, India.
3. **MHRD:** Ministry of Human Resource and Development, New Delhi.